

Enhanced Thermo-Scatter System (ETSS) Refined Work Plan

Contract #: FA864922P1017

Objective #2 Completion

John Edwards

Chief Executive Officer

Levi Kunkel

Chief Technical Officer

Fourth State Communications, LLC

750 Road 138 | Cheyenne, Wyoming 82007 | 760.218.8302 | jedwards@4thstatecommunications.com

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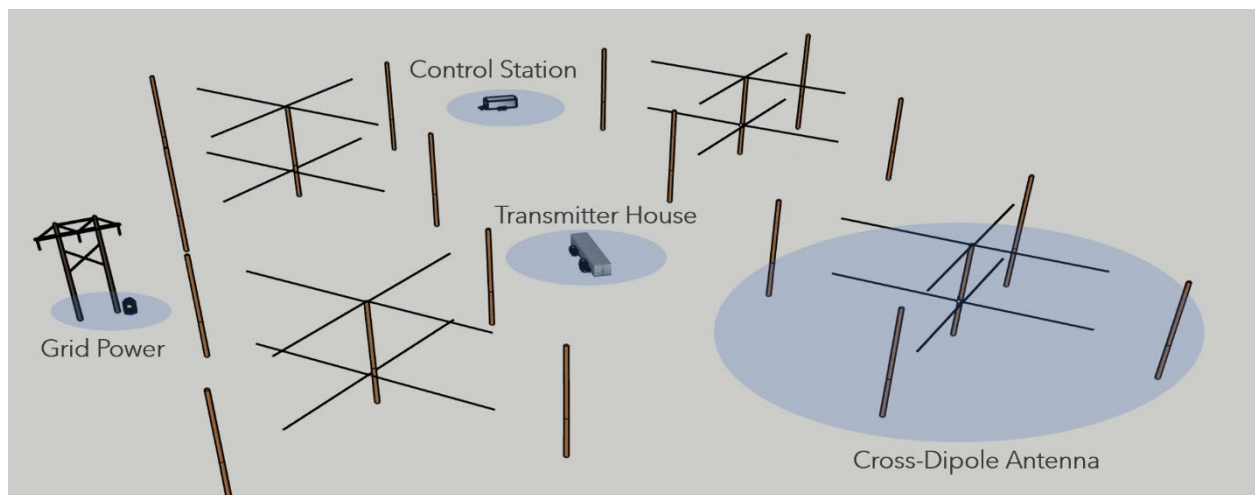
Bottom Line Up Front

The antenna upgrade for completion of Objective #2 has been completed. The completion of Objective #2 will now enable the transmitted power of the Atmospheric Heater to be more than doubled into the Ionosphere. This will increase the electron density of the reflective area created by the Atmospheric Heater to enable higher High Frequency (HF) and Very High Frequency (VHF) links to be more reliably transmitted over-the-horizon.

This antenna upgrade has resulted in a slightly more than doubled Effective Radiated Power (ERP) of the system, taking it from an estimated 1.65MW ERP to an estimated 4.1MW ERP.

Overview

The scope and importance the technical problem is the need to provide alternative communications backhaul capability to the Air Force due to the extreme vulnerabilities that exist regarding all satellite communications. Having a terrestrially based system that will mesh with existing radio equipment will both provide required communications redundancy in a timely manner and come in at a very low cost in comparison to launching more satellites even if that could be done in a rapid manner.



Proposed ETSS with upgraded 3-Element, Quad-Phased Yagi Antennas

The proposed modification to the ETSS is to build and field test better antennas on the existing system to increase ERP from 2.2megawatts (MW) to 4.4MW. By building more highly focused antennas we can concentrate the power emitted by the ETSS causing greater focused energy to create a more reflective atmospheric surface. A good way to think of this to picture a Maglite which uses a set amount of power no matter how focused or unfocused the beam is; with the better antennas we will be effectively focusing the energy to a finer point in the atmosphere.

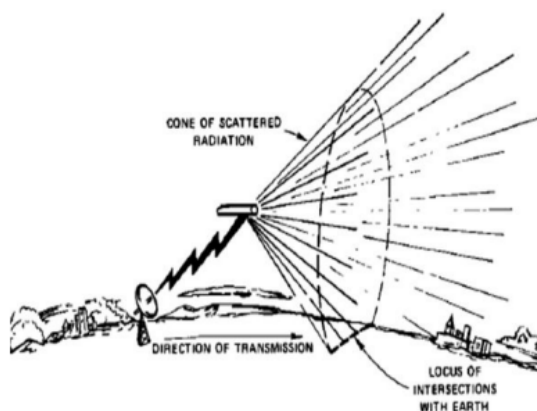
The concept for atmospheric heating is not new. Activities involving atmospheric heating have been conducted since the 1960s. Two examples of Atmospheric Heaters include the High Frequency Active Auroral Research Program (HAARP) in Alaska, as well as the Arecibo Observatory in Puerto Rico. Lesser known Atmospheric Heaters dating back to the 1960s include the Platteville, Colorado Atmospheric Heater and HIPAS, the predecessor to HAARP.

There are two main methods for atmospheric heating; Field Aligned Irregularities (FAIs), and HF Enhanced Ion/Plasma Lines (HFIL/HFPL). This contract will focus on FAIs due to the power constraints of the current system.

FAIs are a naturally occurring phenomenon, but can be artificially created to enable over-the-horizon communications. Previous work has involved VHF transmissions at 2,000 miles. Fourth State Communications has performed its own experiments using the Arecibo Observatory where VHF signals were sent/received at 1,100 miles between Puerto Rico and Brazil. This was again demonstrated naturally using VHF, where the receive signal traversed 800 miles between Colorado and eastern Kansas.

This effort will involve the testing of legacy Air Force radio equipment to determine where current opportunities exist and where improvements can be made to enable future systems for terrestrially based communications capabilities to be over-the-horizon assets.

Geometry of RF scatter from a cylindrical scatterer such as an ionosphere field aligned irregularity (FAI), adapted from Fialer [1974].



Scope of Work Overview

The antenna upgrade will be completed by 15 July 2022. The current ETSS located in Cheyenne, Wyoming is utilizing four single-element cross-dipole antennas, where the elements are 27ft high. The upgraded antennas will be four three-element antenna cross-dipole antennas, where the top (director) cross-dipole element will be at 57ft, the center (driven) cross-dipole element will be at 27ft, and the bottom (reflector) cross-dipole element will be located just above ground level. Upon completion of the antenna build multiple tests will be performed to confirm the performance of the antennas.

The full system test will be completed by 15 November 2022. This will involve bringing the ETSS to full power to confirm the antenna upgrade has been successfully completed. Fourth State Communications

will provide a radar for this effort to determine antenna polarity, phasing, and power are meeting the expectations for over-the-horizon communications use.

Evaluation 1 will be completed by 15 February 2023 and will be performed in coordination with Air Force Launch WERX and executed according to relevant Air Force CONOPS as determined by Launch WERX. This evaluation will involve local HF and VHF testing, as well as over-the-horizon testing where HF and VHF signals will be transmitted between the vicinity of Boulder City, Nevada and Dallas, Texas via the ETSS 'mirror' over Cheyenne, Wyoming. Fourth State Communications will require coordination with Launch WERX to determine HF and VHF radio sets available, frequency requests, and personnel for radio set handling during testing.

Evaluation 2 will be completed by 15 May 2023 and will be performed in coordination with Launch WERX and executed according to relevant Air Force CONOPS as determined by Launch WERX. This evaluation will be conducted in the same manner as Evaluation 1 but will now involve UHF and Troposcatter system testing to be coordinated and provided by Launch WERX. As in Evaluation 1, locations designated in the vicinity of Boulder City, Nevada and Dallas, Texas will be used for the over-the-horizon portion of the test. Fourth State Communications will require coordination with Launch WERX to determine HF and VHF radio sets available, frequency requests, and personnel for radio set handling during testing.

The contract will conclude on 15 August 2023 with the delivery of a final report. The final report will include all testing details and recommendations for future experimentation and operation.

Concept of Operations

As coordination with Launch WERX begins, GANTT Charts and Work Breakdown Structures (WBS) will be provided.

Antenna Upgrade: NLT 15 July 2022

The antenna upgrade will be an internal activity performed by the Fourth State Communications team. The upgrade will consist of removing the current antenna infrastructure and replacing it with Quad-Phased Yagi Antennas. The work will consist of increasing the heights of each of the four current antennas to 57ft, which will allow for the addition of Director Elements at the 57ft height, Driven Elements at the 27ft height, and Reflector Elements at ground level. At the conclusion of the installation, the HF Radar will be used to determine circular polarization is achieved.

The Launch WERX team is welcome to observe both installation and test, but there will be no requirement for it. Fourth State will provide a technical overview of the tests upon completion.

Full System Test: NLT 15 November 2022

The full system test will also be considered an internal objective performed by the Fourth State team. This test will be conducted at full power with HF Radar measurements to determine the polarization of the RF from the Atmospheric Heater as well as power measurements and the characteristics of the heated region of the atmosphere. This Objective is intended to prepare for Evaluation 1&2, so that the system is functioning properly prior to these events.

The Launch WERX team is welcome to observe both installation and test, but there will be no requirement for it. Fourth State will provide a technical overview of the tests upon completion.

Evaluation #1: NLT 15 February 2023

Phase I: HF/VHF Near Vertical Incident Skywave (NVIS) Test

Activity: Local HF/VHF testing in Cheyenne, Wyoming in coordination with Launch WERX.

The intent of this test will be to determine the supportability of an NVIS capability to support missile field communications without the need for radio relays using legacy equipment and frequencies.

Personnel:

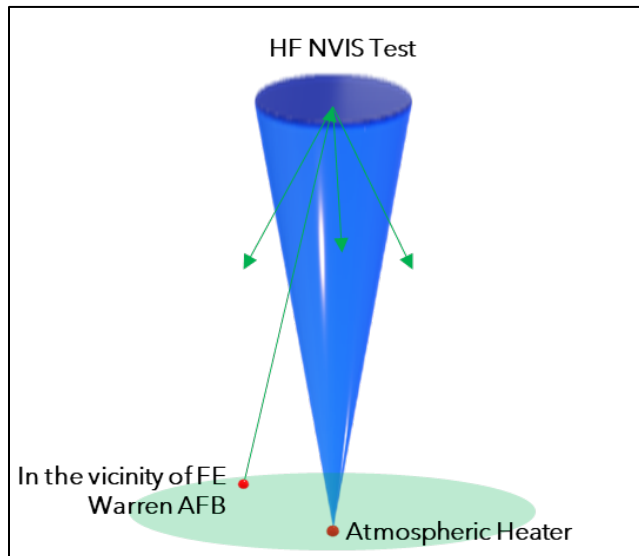
- Launch WERX Team
 - Project Officer
 - HF/VHF Radio Subject Matter Experts
 - Frequency Request Manager
- Fourth State Team
 - Project Manager
 - Atmospheric Scientist
 - Heater Technicians
 - Radar Technicians
 - Logistician

Equipment :

- Launch WERX Team
 - HF Radios (with antennas and amplifiers)
 - VHF Radios (with antennas and amplifiers)
 - Frequencies
- Fourth State Team
 - Atmospheric Heater
 - Radar
 - Additional Antennas
 - Additional Amplifiers

Locations :

- FE Warren AFB
 - Radio Testing Area (In coordination with the Launch WERX Team)



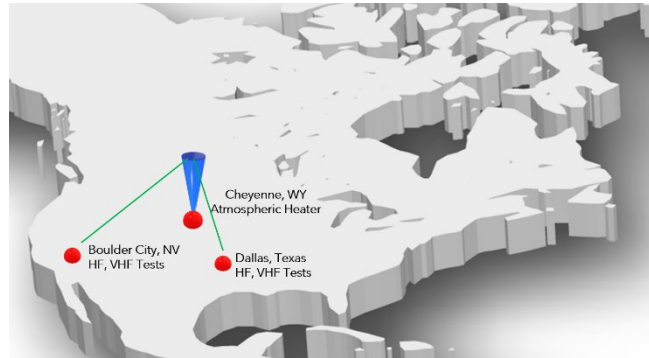
Phase I: HF/VHF NVIS Test

- Atmospheric Heater Location (Swan Ranch Cheyenne, Wyoming)
- Radar Location (In the vicinity of Pierce, Colorado)

Phase II: Over-the-Horizon HF/VHF Test

Activity: HF/VHF testing between Boulder City, Nevada and Dallas, Texas via the Atmospheric Heater located in Cheyenne, Wyoming in coordination with Launch WERX.

The intent of this test will be to determine the supportability of an over-the-horizon HF/VHF capability for the Air Force using legacy equipment and frequencies.



Phase II: Over-the-Horizon HF/VHF Test

Personnel:

- Launch WERX Team
 - Project Officer
 - HF/VHF Radio Subject Matter Experts
 - Frequency Request Manager
- Fourth State Team
 - Project Manager
 - Atmospheric Scientist
 - Heater Technicians
 - Radar Technicians
 - Logistician

Equipment :

- Launch WERX Team
 - HF Radios (with antennas and amplifiers)
 - VHF Radios (with antennas and amplifiers)
 - Frequencies
- Fourth State Team
 - Atmospheric Heater
 - Radar
 - Additional Antennas
 - Additional Amplifiers

Locations :

- Atmospheric Heater Location (Swan Ranch Cheyenne, Wyoming)
- Radar Location (In the vicinity of Pierce, Colorado)
- Site 1 (Boulder City, Nevada)
- Site 2 (Dallas, Texas)

Evaluation #2: NLT 15 May 2023

Activity: UHF testing between Boulder City, Nevada and Dallas, Texas via the Atmospheric Heater located in Cheyenne, Wyoming as well as Troposcatter testing between two straight-line locations to be determined in coordination with Launch WERX.

The intent of this test will be to determine the supportability of an over-the-horizon UHF/Troposcatter capability for the Air Force using legacy equipment and frequencies.

Personnel:

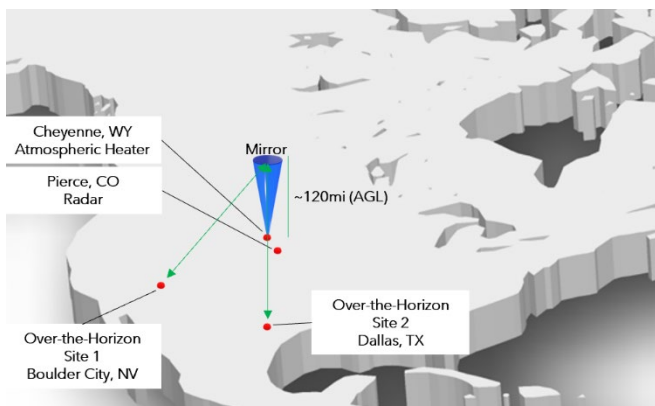
- Launch WERX Team
 - Project Officer
 - UHF/Troposcatter Radio Subject Matter Experts
 - Frequency Request Manager
- Fourth State Team
 - Project Manager
 - Atmospheric Scientist
 - Heater Technicians
 - Radar Technicians
 - Logistician

Equipment :

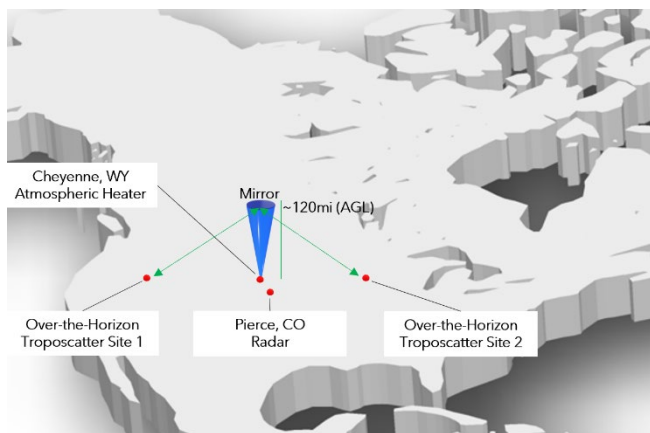
- Launch WERX Team
 - UHF Radios (with antennas and amplifiers)
 - Troposcatter System (with amplifiers)
 - Frequencies
- Fourth State Team
 - Atmospheric Heater
 - Radar
 - Additional Antennas
 - Additional Amplifiers

Locations :

- Atmospheric Heater Location (Swan Ranch Cheyenne, Wyoming)
- Radar Location (In the vicinity of Pierce, Colorado)
- Site 1 (Boulder City, Nevada)
- Site 2 (Dallas, Texas)



Over-the-Horizon UHF Test



Over-the-Horizon Troposcatter Test

- Straight-line Troposcatter Locations (To be determined in coordination with the Launch WERX Team)

Data Collection

The overall intent of the data collection is to determine the optimal frequency at the lowest power level to achieve an over-the-horizon capability with existing equipment sets and organic frequencies. To do this, an established power-level with lowest to highest frequency approach will be pursued. For example, the HF radio to be provided by the Launch WERX team will be initially set to the highest power level at the lowest available frequency. From here, the power will remain the constant as the frequency increases until the signal can no longer be received. This approach will then be repeated at medium power and low power. This approach will be taken across both Evaluations.

The purpose of this approach is to determine the optimal frequency/power combination for equipment sets within the Air Force that can be deployed today, while also informing future opportunities (i.e. airborne assets).



Data Collected	Test Resource	Collection Method	Collector
f_oF2 and E Region Frequency	Boulder, BC840	Recorded/Stored on Hard Drive	Fourth State Personnel
Transmit Frequency	Site #1 VHF Transmitter	Recorded/Stored on Hard Drive	Recorded by Site #1
FAI Frequency Collection	Site #2 VHF Receiver	Recorded/Stored on Hard Drive	Recorded by Site #2
Probable FAI Frequency Collection	Site #3, 4, or 5 VHF Receiver	Recorded/Stored on Hard Drive	Recorded by Site #3, 4, or 5

Personnel

Roles & Responsibilities

Role	Responsibilities	Point of Contact Information
John Edwards	Responsible for the Deliverables of Phase II	jedwards@4thstatecommunications.com

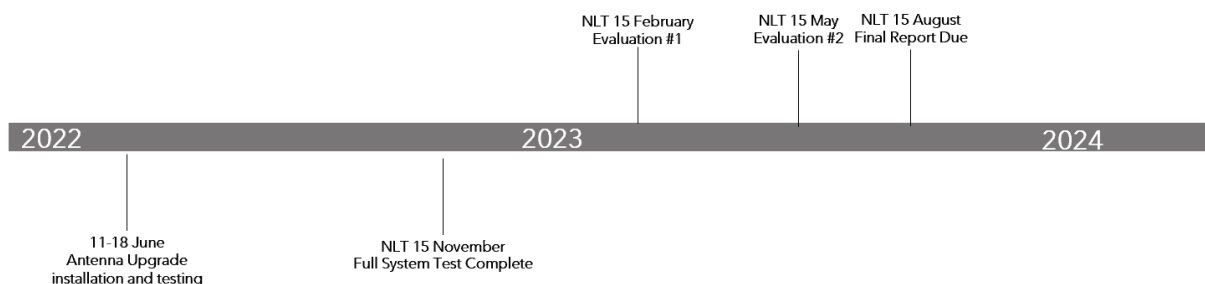
(Principle Investigator)		760.218.8302
Levi Kunkel (Experimental Lead)	Responsible for the design and execution of Experiment 2, as well as delivery of the Final Report	Lkunkel@4thstatecommunications.com 307.287.6851
Jeff Dumps (Operations Lead) (Site #1 Lead)	Responsible for the logistics coordination and site set-up for Experiment 2 Site #2 Lead in Platteville, Colorado	Jdumps@4thstatecommunications.com 907.388.7990
Primary HAM Operator (Site #2 Lead)	Site #2 Lead in Albuquerque, New Mexico	Fourth State Employee
Site #3, #4, or #5 Lead	Mobile team to take advantage of possible hits along extended FAI scatter footprint	As needed, Fourth State Employees

Staffing and training needs

Fourth State Communications is fully staffed and has no further need for staffing.

Launch WERX will provide subject matter experts for each of the equipment sets provided for this effort along with frequency manager coordination, as well as on-base coordination for the NVIS portion of Phase I of Evaluation #1.

Schedule Overview



Licenses

All frequencies related to the Atmospheric Heater and the HF Radar have been approved for use. Launch WERX will need to conduct the coordination for approval of the equipment sets provided.

Test deliverables

A full test report will be provided at the conclusion of this effort.

Points of Contact

The primary point of contact will be the Primary Investigator, John Edwards.

John Edwards

760.218.8302

jedwards@4thstatecommunications.com